An innovative implementation strategy to improve the use of Dutch guidelines on hypertensive disorders in pregnancy

Luitjes, Susanne H.E.; Hermens, Rosella P.M.G.; de Wit, Linda; Heymans, Martijn W.; van Tulder, Maurits W.; Wouters, Maurice G.A.J.

published in
Pregnancy Hypertension
2018

DOI (link to publisher)
10.1016/j.preghy.2018.08.451

document version
Publisher's PDF, also known as Version of record

citation for published version (APA)
Luitjes, S. H. E., Hermens, R. P. M. G., de Wit, L., Heymans, M. W., van Tulder, M. W., & Wouters, M. G. A. J. (2018). An innovative implementation strategy to improve the use of Dutch guidelines on hypertensive disorders in pregnancy: A randomized controlled trial. *Pregnancy Hypertension*, *14*, 131-138. https://doi.org/10.1016/j.preghy.2018.08.451

Pregnancy Hypertension 14 (2018) 131–138

Contents lists available at ScienceDirect

Pregnancy Hypertension

journal homepage: www.elsevier.com/locate/preghy

An innovative implementation strategy to improve the use of Dutch guidelines on hypertensive disorders in pregnancy: A randomized controlled trial

Susanne H.E. Luitjes[a,b,*], Rosella P.M.G. Hermens[c], Linda de Wit[a], Martijn W. Heymans[b], Maurits W. van Tulder[b], Maurice G.A.J. Wouters[a]

[a] Department of Obstetrics and Gynaecology, VU University Medical Centre, PO Box 7057, 1007 MB Amsterdam, The Netherlands
[b] Department of Health Sciences, Faculty of Earth & Life Sciences, Amsterdam Public Health Institute, VU University, De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands
[c] Radboud Institute for Health Sciences (RIHS), Scientific Institute for Quality of Health Care (IQ Healthcare), Radboud University Medical Centre (Radboudumc), PO Box 9101, 6500 HB Nijmegen, The Netherlands

ARTICLE INFO

Keywords:
Randomized controlled trial
Implementation
Decision support system
Guidelines
Process evaluation

ABSTRACT

Objective: To evaluate the effectiveness of an innovative strategy to improve implementation of evidence-based guidelines on the management of hypertension in pregnancy compared to a common strategy of professional audit and feedback.
Design: Cluster randomized controlled trial (c-RCT).
Setting: Sixteen Dutch hospitals.
Population: All patients with a hypertensive disorder during pregnancy who were admitted to one of the participating hospitals between April 1st 2010 and May 1st 2011, were suitable for inclusion; the only exclusion criterion was the presence of lethal fetal abnormalities.
Methods: Hospitals were randomly assigned to either an innovative implementation strategy including a computerized decision support system (DSS) and professional audit and feedback or a minimal implementation strategy of audit and feedback only.
Main outcome measures: Primary outcome measure was a combined rate of major maternal complications. Secondary outcome measures included process-related measures on guideline adherence, and patient-related outcomes. A process evaluation was performed alongside.
Results: No statistically significant difference was found in both the occurrence of major complications and most secondary outcome measures between the two groups. Process evaluation showed limited use of the computerized DSS, with a large variation between hospitals (0–49,5% of the eligible patients), but positive experiences of actual users.
Conclusion: Using a computerized DSS for implementation of the clinical guidelines for the management of hypertension in pregnancy did not result in fewer major maternal and fetal complications. Limited use of the DSS in the innovative strategy group could be an explanation for the lack of effect.

1. Introduction

Seventeen percent of all clinical pregnancies are complicated by hypertension and two percent by preeclampsia [1–6]. Hypertensive disorders in pregnancy are one of the main causes of maternal mortality and morbidity worldwide. Several clinical guidelines have been developed worldwide to provide pregnant women with hypertensive disorders with the best available healthcare [7]. Purpose of clinical guidelines is to support healthcare providers, decrease practice variation, and ultimately improve patient outcomes. However, the mere existence of these guidelines does not automatically imply that they are widespread or commonly used. Case analyses of adverse maternal outcomes showed a high level of substandard care [8]. Dissemination of new guidelines should ideally be followed by robust implementation efforts. Research on the implementation of obstetrical guidelines is scarce. It is commonly known in guideline implementation research

* Corresponding author at: Department of Obstetrics and Gynaecology, VU University Medical Centre, PO Box 7057, 1007 MD Amsterdam, The Netherlands.
E-mail address: s.luitjes@vumc.nl (S.H.E. Luitjes).

https://doi.org/10.1016/j.preghy.2018.08.451
Received 5 March 2018; Received in revised form 8 August 2018; Accepted 19 August 2018
Available online 27 September 2018

Table 1
Final set of key recommendations eligible for indicator transcription per guideline and indicator-type.

Guideline 'Hypertensive disorders in pregnancy'	Type of indicator
Patients with severe preeclampsia need to be adequately stabilized before intervention (transport to tertiary care centres and/or delivery). Treatment exists of magnesium sulphate and/or antihypertensive drugs depending on the blood pressure.	Process
First treatment to prevent eclampsia needs to exist of magnesium sulphate.	Process
When improvement fails to occur or deterioration occurs with patients with severe preeclampsia, the physician needs to terminate the pregnancy.	Process
Systolic blood pressure ≥ 170 mmHg and/or diastolic blood pressure ≥ 110 mmHg in a patient with gestational hypertension or preeclampsia needs to be treated with drugs.	Process
Target values for the systolic blood pressure are 140–160 mmHg and 90–105 mmHg for the diastolic blood pressure in patients with preeclampsia.	Process
Patients with moderate-severe gestational hypertension need to be informed by their physician about the possibility of acute worsening of the disorder and the necessity to contact their physician when experiencing symptoms.	Process
The physician needs to perform laboratory examination: haemoglobin, haematocrit, creatinine, platelets, lactate dehydrogenase (LDH) and alanine aminotransferase (ALAT) in case a patient presents with subjective symptoms of preeclampsia, in case of proteinuria or severe (gestational) hypertension.	Process
Treatment of patients with severe preeclampsia needs to be a clinical one.	Process
The physician needs to start magnesium sulphate when a patient has symptoms of severe preeclampsia.	Process
The physician needs to perform urine examination for proteinuria when a patient is diagnosed with gestational hypertension.	Process
The hospital needs to have a regional consent concerning consultation or transportation to a perinatal centre for patients with severe preeclampsia before 32 weeks gestation or severe maternal morbidity.	Structure
Every hospital needs to have a (local) protocol for treatment of patients with gestational hypertension, preeclampsia or HELLP.	Structure

that there is no 'magic bullet' for successful implementation of every clinical problem or in every practice setting [9–12]. The most frequently studied interventions encompass audit and feedback on current practice, dissemination of educational materials, reminders and the organization of educational meetings or outreach visits, which all seem to have only small to moderate effects on the improvement of professional performance [13–15].

Chaudry et al., demonstrated a major benefit of implementing health information technology on increased adherence to guideline-based care, amongst others in hypertension [16]. Different health information technology systems were reviewed. Most of them included a decision support system (DSS), and some integrated clinical guidelines [17]. In 2005–2006, the departments of Obstetrics and Gynecology of the VU University Medical Centre in Amsterdam and the University Medical Centre Utrecht tested and evaluated the feasibility of using a DSS for the Dutch Society of Obstetrics and Gynecology (NVOG) guideline on the treatment of prevention of neonatal Group B Streptococcus disease. In the evaluation, the DSS appeared feasible in clinical practice: most users (95%) were satisfied with its use and 78% would prefer to maintain and extend the DSS to other NVOG guidelines [18,19]. We hypothesized that an implementation strategy including a DSS may lead to a higher compliance to the guidelines' recommendations on hypertensive disorders in pregnancy [20,21] and thus a lower rate of maternal complications than a minimal implementation strategy consisting of a single intervention of audit and feedback only. We designed a cluster randomized controlled trial (c-RCT), the BIG CHANGE (**B**OS supported **I**mplementation of **G**uidelines on **C**linical **H**ypertension and its m**ANA**gement in **GE**station) trial, to study the effects of an innovative implementation strategy to improve the use of national obstetrical guidelines on hypertension in pregnancy, consisting of a multifaceted intervention (computerized DSS plus audit and feedback), tailored to barriers from the literature and directed at obstetrical professionals. To increase our understanding of factors influencing the impact of the implementation strategy, a process evaluation of the trial was also performed.

2. Materials and methods

2.1. Study design

We performed a c-RCT in 16 hospitals in three regions of The Netherlands. The research ethics committee of VU University Medical Centre approved the study. The trial was registered with trialregister.nl (ID NTR 1387). Further details of the study design have been described elsewhere [22].

2.2. Randomization

Hospitals were randomly assigned to either the innovative implementation strategy group (computerized DSS plus audit and feedback) or the minimal implementation strategy group (audit and feedback only). Prior to randomization, participating hospitals were stratified according to function (academic hospitals, teaching hospitals and non-teaching hospitals). To ensure concealment of treatment allocation two research associates, blinded for characteristics of the clinics, performed per stratum the randomization procedure by drawing sealed, opaque envelopes.

2.3. Participants

2.3.1. Hospitals

All 16 hospitals that were invited agreed to participate. Two of them were large, academic hospitals, nine hospitals were medium-sized, teaching hospitals; the other five were small, non-teaching hospitals. The different types were chosen to reflect national obstetrical care.

2.3.2. Patients

All patients with a hypertensive disorder during pregnancy who were admitted to one of the participating hospitals were suitable for inclusion; the only exclusion criterion was the presence of lethal fetal abnormalities. A pre-implementation measurement was performed in each hospital, which included a random sample of patients that were admitted with a hypertensive disorder during their pregnancy in 2008. For the measurement after introduction of both implementation strategies, all patients admitted to one of the hospitals between April 1st 2010 and May 1st 2011 with a hypertensive disorder during their pregnancy were included.

2.4. Study interventions

2.4.1. Minimal implementation strategy

The minimal implementation strategy, implemented in 8 hospitals, was directed at professionals (obstetricians and gynecologists) and consisted of professional audit and feedback. Audit comprised results of the pre-implementation measurement of the hospital's scores to 12 previously developed quality indicators (Table 1) regarding care provided in 200823. Based on these indicator scores, hospital-specific feedback reports were formulated by the study group. The contact person of each hospital was sent a feedback report by email, asking them to forward copies to their colleagues (i.e. gynecologists, residents and clinical midwifes). An instruction letter was enclosed to facilitate interpretation of the feedback report. Feedback on current care was

given by means of a bar chart showing the total range of performance per quality indicator on a scale from 0 to 100% including the median adherence of all participating hospitals and the median of its peer hospitals (academic, teaching, non-teaching). Each individual hospital also received a clear marking of their performance in the bar chart, but hospitals did not get information of the performance of other individual hospitals. This was only available on aggregate level. No further contact was established with the minimal implementation strategy hospitals until the data collection for the post-implementation measurement was started.

2.4.2. Innovative implementation strategy

The innovative strategy, implemented in the other 8 hospitals, was multi-faceted and included the following two professional-oriented elements:

(i) Audit and feedback discussions: Similar to the minimal strategy, hospital-specific feedback reports were developed and sent to the eight innovative implementation strategy hospitals in April 2010. After four weeks, a multi-disciplinary (e.g. addressing gynecologists, residents and clinical midwifes) meeting was organized in each hospital in which the feedback report was presented and commented by one of the authors. During each meeting, the hospital's performance was compared with the other 15 hospitals' performances and possibilities for quality improvement were discussed.

(ii) A computerized DSS, including a web-application, was developed (by Giant Soft, Leeuwarden, The Netherlands) to assist the professionals in providing optimal care for the patients admitted to their hospital[22]. For each patient and fetus several characteristics had to be filled in: gestational age, systolic and diastolic blood pressure, complaints of headache, pain in upper right part of the abdomen, vision problems, if laboratory testing was done and if so, were they normal or abnormal, if urine had been tested for proteinuria and if so, what was the result. The fetal characteristics contained fetal growth and cardiotocography (CTG) findings. When all data were entered in the DSS, recommendations of the Dutch guideline regarding hypertensive disorders in pregnancy, tailored to the specific woman, were provided within seconds.

2.5. Outcomes

The primary outcome of this trial was a combined rate of major maternal complications (maternal death, organ specific complications of hypertension, HELLP syndrome and placental abruption). All medical records were checked on the presence of these complications both in the pre- and post-implementation measurement.

Secondary outcome measures included process-related measures on guideline adherence, and patient-related outcomes (caesarean delivery rates, and rates of neonatal mortality and morbidity). Guideline adherence rates were measured using quality indicators. These indicators (structure and process indicators) were extracted from two obstetrical guidelines of the NVOG: 'hypertensive disorders in pregnancy' and 'chronic hypertension and pregnancy' [20–21] and systematically developed [23]. Adherence to guideline indicators was scored dichotomously, 'adherence' vs. 'non-adherence'. The indicators covered topics like 'indications for treatment', 'treatment options', 'patient monitoring' and 'patient information'. All indicators were tested during the pre-implementation measurement for several quality criteria (i.e. measurability, reliability, applicability, improvement potential, discriminatory capacity and complexity), thus exploring their value for monitoring and improving clinical performance. After the pre-implementation measurement, indicators with high measurability, reliability and applicability were considered adequate measures of adherence to guideline recommendations (Fig. 1).

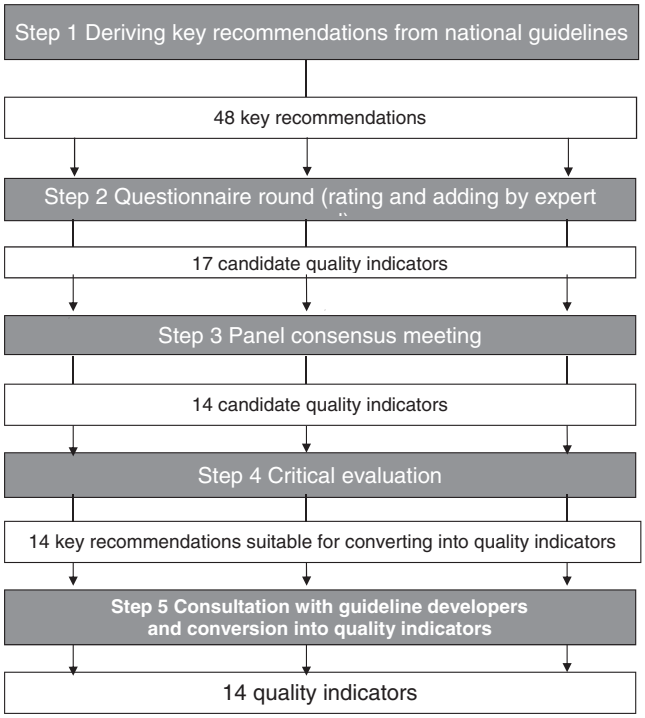

Fig. 1. A step-wise RAND-modified Delphi method to develop quality indicators for care for patients with hypertensive disorders in pregnancy.

2.6. Data collection

2.6.1. Effect evaluation

Data were collected from medical records (e.g., maternal complications, process measures on guideline adherence and secondary patient-related outcomes). Each record was verified to determine the presence or absence of major maternal complications, caesarean delivery, rates of neonatal mortality and morbidity. Items necessary to calculate the quality indicators were collected as well. Medical record extraction was performed by two trained data collectors who entered data in digital forms, specifically designed to enhance systematic and complete data collection by using computerized algorithms for data entry.

2.6.2. Process evaluation

We also performed a process evaluation of the innovative implementation strategy to assess use of and experiences with the DSS. In all eight hospitals randomized to this strategy residents and clinical midwifes collected user data. In addition, professionals involved in obstetric care were contacted and asked to fill in an online questionnaire containing questions on efficiency (time saving and appropriate advice), barriers (familiarity, accessibility and applicability of DSS) and points for improvement (legibility, extension, clarity an expansion of DSS). An email containing a link to the questionnaire was sent to all users.

2.7. Sample size and feasibility

The rate of major maternal complications in 216 Dutch patients with severe hypertension or preeclampsia was reported as 34% [24,25]. In 96% of cases of maternal death, The Dutch Maternal Mortality Committee determined several factors of substandard care, which were classified as insufficient treatment of hypertension in about half of these [8,26]. It was expected that an increased adherence to the guidelines' recommendations would reduce the number of major maternal complications by half, i.e. from 34% to 17%. Considering an intracluster

correlation of 0.05, 16 hospitals had to be included with approximately 25 patients each in order to get a reliable estimate (alpha = 0.05; power 0.80) of a 50% difference (34% vs. 17%) in major maternal complications between both groups. We assumed that 15% of participants would drop-out or be lost to follow-up, so 472 eligible women needed to be included, 236 in the innovative implementation strategy arm and 236 in the minimal implementation strategy arm.

2.8. Analysis

Data were analyzed using IBM SPSS Statistics 20. To analyze the difference in effectiveness of the innovative implementation strategy compared to the minimal strategy on the primary and secondary outcomes, we assessed the proportion of patients that developed major complications before and after the implementation period in both groups. Also, both groups were compared with each other, before and after the implementation period. For each complication, generalized estimating equation (GEE) models were used to control for the dependency of observations within hospitals in which 'implementation strategy' acted as the independent variable and 'complication score' as the dependent variable.

To analyze the difference in effectiveness of the two strategies on process-related measures, we assessed the proportion of patients that were treated in accordance with the guidelines. Quality indicator scores before and after the implementation period in both intervention groups were assessed. Within and between group differences were analyzed with adjustment for clustering of patients within clinics. Therefore, for each indicator, also GEE models were used in which 'implementation strategy' acted as the independent variable and 'indicator score' as the dependent variable.

For the data analyses of the process evaluation descriptive statistics were used, both regarding usage rates of (% of eligible patients for which the DSS was used) and experiences with the DSS. Wilcoxon signed rank test with a two-sided confidence interval of 5% was used for the comparison between the two groups.

All analyses were based on the intention-to-treat principle, meaning all participants were included in the analysis in the group to which they were originally assigned, regardless of whether they received the implementation strategy or not. Differences in the pre-implementation measurement period were corrected for by including these scores as a covariate in the final GEE model.

3. Results

3.1. Participant flow

In the pre-implementation measurement period, 270 patients were included in the innovative and 262 in the minimal implementation strategy group. In the post-implementation measurement period, 947 patients were included in the innovative strategy group and 815 patients in the minimal strategy group.

3.2. Comparability of groups

Demographic characteristics of both groups at both measurement periods are shown in Table 2.

Both groups are comparable on both measurement moments.

3.3. Outcomes and estimation

3.3.1. Primary outcomes

Table 3 and 4 show the rates of the primary outcomes before and after the implementation in both groups. Major maternal complications were statistically significant lower post-implementation in both the innovative implementation and the minimal implementation strategy group when compared to the pre-implementation results (OR 0.64 [95% CI 0.42–0.96] and OR 0.70 [95% CI 0.55–0.89], respectively). There was neither a statistically significant difference in the occurrence of major complications between the innovative implementation group and the minimal implementation strategy group pre-implementation (OR 0.77; 95% CI 0.41–1.42) nor post-implementation (OR 1.13; 95% CI 0.66–1.9).

3.3.2. Secondary outcomes

Table 5 shows the results for the secondary patient-related outcomes. Between pre- and post-implementation there was a statistically significant increase in neonatal mortality (OR 3.30;1.83–5.96) and decrease in caesarean sections (OR 0.47;0.50–0.76) in the minimal implementation group; there were no significant changes in the innovative implementation group. There were no statistically significant differences between the two groups on any of these outcomes pre- nor post-implementation. Table 6 shows the indicator scores for guideline adherence. Results demonstrated that in both the innovative and the minimal implementation strategy group guideline adherence improved after implementation. Laboratory testing statistically significantly improved more in the innovative implementation strategy group compared to the minimal implementation strategy group.

3.4. Process evaluation

The actual use of the DSS showed that data from in total 234 patients (24.7%) were entered in the innovative computerized system. The highest usage rate per hospital was 49.5%, the lowest 0%. Most patients were included in 5 out of 8 hospitals, usage rates ranging from 20% to 49.5% (Fig. 2).

Gynecologists, residents and clinical midwifes of six of the eight hospitals in the innovative strategy group answered the questionnaire regarding the process evaluation. A total of 34 (68%) completed questionnaires were used for analysis. Positive opinions on user friendliness, clarity, speed of the program, lay-out, clearness and end report varied from 73.5% to 100% of the participants. On the question if a DSS was a suitable tool for implementation of a guideline, 91% answered affirmative. Most of the respondents (85%) found it useful to develop a computer based support system for other NVOG guidelines, and 79% intended to use a DSS, if available, for other guidelines. Fifty-eight percent found using DSS easier than their local protocol or the NVOG guideline. Improvements mentioned by the respondents concerned the lay-out, and login name and password. Login names and passwords were provided by the research team, but most respondents preferred choosing their own login and password.

3.5. Discussion

We report results of a randomized controlled trial that evaluated the implementation of obstetrical guidelines concerning hypertensive disorders in pregnancy comparing a multifaceted innovative and a minimal implementation strategy. The multifaceted innovative implementation strategy consisted of a computerized decision support system combined with audit and feedback, the minimal implementation strategy of audit and feedback only. There were no statistically significant differences in clinical outcomes between the innovative implementation strategy group and the minimal implementation strategy group. The innovative implementation strategy increased guideline adherence on one item only, particularly an improvement in laboratory testing. Process evaluation showed limited use of the computerized DSS, with a large variation between hospitals (0–49,5%), but positive experiences of actual users.

We consider the significant improvement in laboratory testing in the innovative implementation strategy group mainly a finding by chance, because it is difficult to explain why there was a higher rate of laboratory tests, and the estimates were rather uncertain as the confidence intervals were wide.

Table 2
Comparability of groups.

	Minimal implementati on group 2008 N = 262	Innovative implementati on group 2008 N = 262	Minimal implementati on group 2011 N = 815	Innovative implementati on group N = 947	*P	**p
Age	31.32	30.88	30.97	31.44	0.755	0.254
Parity						
-Nulliparous	185	188	556	654	0.650	0.850
-Multiparous	77	82	259	293		
Gestation						
-Term	163	176	651	696	0.614	0.527
-Preterm	98	93	162	251		
Ethnicity						
-Dutch	204	204	472	654	0.587	0.507
-Mediterranean	29	26	30	49		
-Other	15	18	12	30		
European	2	7	1	5		
-Hindu	8	13	22	31		
-African	2	2	10	22		
-Other	1	0	268	143		
-Unknown						
Diagnosis						
-Pregnancy induced hypertension (PIH)	80	86	367	337	0.411	0.825
-Preeclampsia (PE)	126	119	259	408		
-HELLP	7	11	10	16		
-Superimposed PE	31	28	94	111		
-PIH and HELLP	4	4	23	26		
-PE and HELLP	14	19	44	46		
Multiple pregnancy						
-Twin	13	9	18	44	0.869	0.389
Origin						
-Midwife	190	186	619	682	0.889	0.204
-Non academic hospital	58	75	179	215		
-Academic hospital	14	9	16	44		

*p innovative implementation (intervention) 2008 vs minimal implementation (control) 2008.
**p innovative implementation (intervention) 2011 vs minimal implementation (control) 2011.

Table 3
Primary outcome.

1			
	2008 N = 270	2011 N = 947	OR (95% CI)
	38 (14.1%)	100 (10.6%)	0.64 (0.42–0.96)
2			
	2008 N = 262	2011 N = 815	OR (95% CI)
	44 (16.8%)	104 (12.8%	0.70 (0.55–0.89)
3			
	Innovative implementation N = 270	Minimal implementation N = 262	OR (95% CI)
	38 (14.1%)	44 (16.8%)	0.77 (0.41–1.42)
4			
	Innovative implementation N = 947	Minimal implementation N = 815	OR (95% CI)
	100 (10.6%)	104 (12.8%)	1.13 (0.66–1.9)

1. Innovative implementation strategy group 2008 vs 2011.
2. Minimal implementation strategy group 2008 vs 2011.
3. Innovative implementation strategy group 2008 vs minimal implementation strategy group 2008.
4. Innovative implementation strategy group 2011 vs minimal implementation strategy group 2011.

Not having found a statistically significant effect of the innovative implementation strategy raises the question whether this strategy is ineffective, or whether ineffectiveness is largely caused by flaws in the study design or incomplete execution of the intervention strategy. We will further elaborate on these possibilities.

During the study period, obstetric management of hypertensive disorders in the Netherlands was significantly changed by the results of the HYPITAT trial [27]. This multicenter, parallel, open-label randomized controlled study was conducted between October 2005 and March 2008 in 6 academic and 32 non-academic Dutch hospitals. It was then demonstrated that induction of labour is associated with improved maternal outcome in women with mild hypertensive disease beyond 37 weeks' gestation [27]. A recent evaluation showed that participation in the HYPITAT trial has led to an increase of induction of labour from 58.3 to 67.1% ($P < 0.001$) and a decrease of prevalence of eclampsia from 0.85 to 0.19% ($P < 0.001$) before and after the trial in the Netherlands [28]. The results of this study could explain why there is no difference in clinical outcomes between the innovative strategy group and the minimal strategy group. Expectative management for these disorders has decreased compared to the period before the HYPITAT trial and awareness of the possible maternal and neonatal complications has increased, which may have lowered the incidence of these complications. A lower incidence of major maternal complications in both

Table 4
Percentage of major complications for the innovative implementation strategy and the minimal implementation strategy.

	2008 (%)		2011 (%)		OR (95% CI)	
Innovative implementation strategy	38/270	(14.1)	100/947	(10.6)	0.64	(0.42–0.96)
Minimal implementation strategy	44/262	(16.8)	104/815	(12.8%)	0.70	(0.55–0.89)

Table 5
Secondary outcomes: patient related outcomes.

1				
	Innovative implementation group 2011 N = 947	Innovative implementation group 2008 N = 270	P	OR (95% CI)
Neonatal mortality	10 (1.1%)	3 (1.1%)	0.73	0.83 (0.29–2.39)
Dysmaturity	65 (6.9%)	27 (10%)	0.13	0.64 (0.36–1.14)
Asphyxia	72 (7.6%)	19 (7.0%)	0.94	0.98 (0.64–1.52)
Cesarean Section	252 (26.6%)	95 (35.2%)	0.27	0.82 (0.59–1.16)
2				
	Minimal implementation group 2011 N = 815	Minimal implementation group 2008 N = 262	P	OR (95% CI)
Neonatal mortality	8 (0.99%)	1 (0.38%)	< 0.0001	3.30 (1.83–5.96)
Dysmaturity	60 (7.4%)	20 (7.6%)	0.90	0.98 (0.67–1.43)
Asphyxia	44 (5.4%)	19 (7.3%)	0.31	0.77 (0.44–1.29)
Cesarean Section	216 (26.5%)	102 (38.9%)	< 0.0001	0.47 (0.50–0.76)
3				
	Innovative implementation group 2008 N = 270	Minimal implementation group 2008 N = 262	P	OR (95% CI)
Neonatal mortality	3 (1.1%)	1 (0.38%)	0.31	3.12 (0.35–27.86)
Dysmaturity	27 (10%)	20 (7.6%)	0.34	1.41(0.67–3.13)
Asphyxia	19 (7.0%)	19 (7.3%)	0.84	1.05 (0.67–1.65)
Cesarean Section	95 (35.2%)	102 (38.9%)	0.33	0.84 (0.59–1.20)
4				
	Innovative implementation group 2011 N = 947	Minimal implementation group 2011 N = 815	P	OR (95% CI)
Neonatal mortality	10 (1.1%)	8 (0.99%)	0.76	0.78 (0.15–3.95)
Dysmaturity	65 (6.9%)	60 (7.4%)	0.73	0.94 (0.68–1.31)
Asphyxia	72 (7.6%)	44 (5.4%)	0.10	1.47 (0.93–2.32)
Cesarean Section	252 (26.6%)	216 (26.5%)	0.62	1.10 (076–1.60)

1. Innovative strategy group 2008 vs 2011.
2. Minimal strategy group 2008 vs 2011.
3. Innovative strategy group vs minimal strategy group 2008.
4. Innovative strategy vs minimal strategy group 2011.

groups after the study period confirms our hypothesis (Table 3).

As an attempt to reduce the high perinatal mortality in the Netherlands, a nationwide implementation of audits was started in 2009. During a perinatal audit (local, regional or national) health care professionals (gynecologists, midwives, pediatricians, nurses and pathologists) critically analyze in a structured way the care provided in cases of perinatal death. These audits resulted in a greater focus on the possible causes of perinatal mortality and this may have led to increased awareness of the risks of pregnant women with hypertensive disorders during our study period in both the innovative strategy group and the minimal strategy group.

In addition, the researchers of the LEMMON study, a Dutch prospective study of severe maternal morbidity conducted between 2004 and 2006 [29], published several articles in 2008 and 2009. They collected 2552 cases of severe maternal morbidity. Substandard care was found in 62% of these cases through clinical audit. These results may also have contributed to more awareness and the improvement of care for pregnant women in both groups.

Besides a reduction in major maternal complications during the study period in both groups the rate of major maternal complications before implementation of the guideline in 2010–2011 was lower than expected based on the results of previous studies. This may be explained by the fact that our study was performed in academic as well as non-academic hospitals, whereas former studies [24,25] were performed in academic hospitals only, thus including a high-risk population.

With regard to the effectiveness of implementation strategies, their success depends on optimal use and positive experiences. Insight into these factors could be obtained in a process evaluation. In our study, the difference between the innovative and minimal strategy was the DSS, so we particularly included a process evaluation of the DSS. The majority of patients were included in the intervention group in 5 out of 8 hospitals of the innovative implementation strategy group. One hospital did not include a single patient, despite several reminders. Although the users were generally enthusiastic about the DSS, ultimately, in only a quarter of all eligible patients the DSS was used. This could also explain the ineffectiveness of the DSS.

A reason for not using the DSS could be that it was not integrated in the routine of daily practice. A systematic review from Chaudhry et al. demonstrated that the effectiveness of a computerized DSS was higher if it was integrated in an electronic patient file [16]. We hypothesize that using computerized DSS to implement evidence based guidelines could be more effective when the system is combined with an automatically imbedded system of reminders, therapeutic suggestions and diagnosis-specific links to guidelines [30]. Besides, results from a comparable study among gynecologists of Mourad et al. showed that professionals either were quite indifferent to an innovative strategy type or did not consider it their job to do so [31].

Moreover, several Cochrane systematic reviews have shown that the impact of different strategies to promote healthcare interventions is widely variable, mostly with small to modest effects on improving professional practice [15]. Our assumption that an increased adherence to the guidelines' recommendations will reduce the number of major maternal complications by half (50%) was most likely too optimistic. A review of evidence-based strategies for implementing guidelines in obstetrics showed especially positive effects for interventions including audit and feedback, reminders and multifaceted strategies [32]. Although it is clearly demonstrated that the prospective identification of barriers to change leads to better adaptation of interventions, this was not demonstrated in our study. Although we used a multifaceted strategy, including audit and feedback, and adapted the DSS to previous barriers, we did not find positive effects. As mentioned above, the limited use of DSS could be an explanation.

3.6. Strengths and weaknesses of the study

One of the strengths of this study is the use of a c-RCT to evaluate the effect of the tested interventions, as this is considered the 'gold standard' in implementation research [33]. Randomization was performed at hospital rather than professional or patient level to avoid any risk of contamination of both study arms. Sixteen hospitals participated,

Table 6
Secondary outcomes process related: guideline adherence.

1				
	2011 N = 947	2008 N = 270	P	OR (95% CI)
Stabilization	575 (60.7%)	123 (45.6%)	0.0001	3.81 (1.94–7.49)
Mg504	225 (23.8%)	65 (24.1%)	< 0.0001	3.95 (2.41–6.46)
Antihypertensive drugs	498 (52.6%)	119 (44.1%)	0.008	1.96 (1.19–3.11)
Blood pressure	919 (97.0%)	240 (88.9%)	0.007	2.66 (1.30–5.43)
Information	242 (25.6%)	160 959.3%)	0.09	0.38 (0.12–1.19)
Laboratory tests	920 (97.1%)	266 (98.5%)	0.0002	13.60 (3.47–53.34)
Urine test	928 (98.0%)	270 (100.0%)	0.78	0.87 (0.47–1.02)
2				
	2011 N = 815	2008 N = 262	P	OR (95% CI)
Stabilization	454 (55.7%)	187 (71.4%)	0.0001	6.23 (2.44–15.92)
Mg504	194 (23.8%)	62 (23.7%)	0.001	3.76 (1.71–8.24)
Antihypertensive drugs	418 (51.3%)	106 (40.5%)	0.012	3.94 ((1.35–11.52)
Blood pressure	768(94.2%)	245 (93.5%)	0.013	4.00 (1.34–11.94)
information	223 (27.4%)	115 (43.9%)	0.024	0.50 (0.28–0.91)
Laboratory tests	780 (95.7%)	226 (86.3%)	0.92	0.88 (0.06–12.33)
Urine test	794 (97.4%)	270	0.66	0.884 (0.51–1.54)
3				
	Innovative implementation group 2008 N = 270	Minimal implementation group 2008		
N = 262	P	OR (95% CI)		
Stabilization	123 (45.6%)	187 (71.4%)	0.78	1.14 (0.46–2.85)
Mg504	65 (24.1%)	62 (23.7%)	0.77	0.90 (0.44–1.83)
Antihypertensive drugs	119 (44.1%)	106 (40.5%)	0.45	1.58 (0.49–5.10)
Blood pressure	240 (88.9%)	245 (93.5%)	0.89	1.08 (0.34–3.40)
Information	160 (59.3%)	115 (43.9%)	0.94	1.05 (0.28–3.99)
Laboratory tests	266 (98.5%)	226 (86.3%)	0.23	0.26 (0.03–2.30)
Urine test	270(100.0%)	258 (98.5%)	0.43	1.87 (0.39–8.92)
4				
	Innovative implementation group 2011 N = 947	Minimal implementation group 2011		
N = 815	P	OR (95% CI)		
Stabilization	575 (60.7%)	454 (55.7%)	0.78	0.87 (0.31–2.41)
Mg504	225 (23.8%)	194 (23.8%)	0.93	1.05 (0.37–3.00)
Antihypertensive drugs	498 (52.6%)	418 (51.3%)	0.95	0.97 (0.34–2.79)
Blood pressure	919 (97.0%)	768 (94.2%)	0.85	0.89 (0.26–3.06)
Information	242 (25.6%)	223 (27.4%)	0.41	0.83 (0.53–1.30)
Laboratory tests	920 (97.1%)	780 (95.7%)	0.04	9.72 (1.14–82.92)
Urine test	928 (98.0%)	794 (97.4%)	0.26	1.87 (0.63–5.58)

1. Innovative implementation strategy group 2008 vs. 2011.
2. Minimal implementation strategy group 2008 vs. 2011.
3. Innovative strategy group vs. minimal strategy group 2008.
4. Innovative strategy group vs. minimal strategy group 2011.

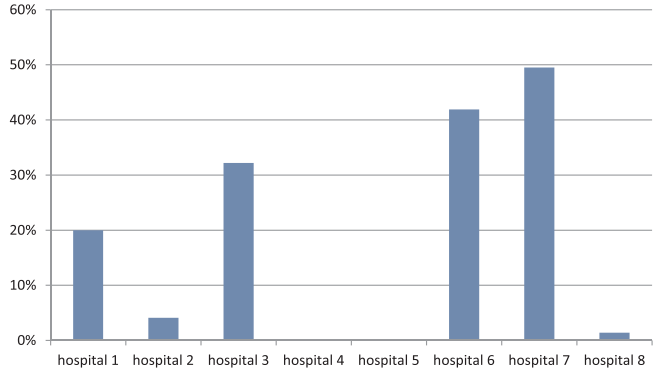

Fig. 2. Percentage of patients included in the participating hospitals. X-axis: number of patients per hospital that should have been included. Y-axis: percentage of included patients per hospital.

with a good reflection of possible practice variation (academic, teaching and non-teaching hospitals to represent the Dutch health system). Another strength is that only two researchers were involved in checking the medical files. This decreased the chance of interobserver variation and bias. In addition, our innovative strategy was tailored to barriers identified by our previous research, which is also seen as a facilitator for implementation [22].

We realize that there are some limitations to our study as well. An important one is that this study did not achieve enough statistical power. We expected that an increased adherence to the guidelines' recommendations would reduce the number of major maternal complications by half, i.e. from 34% to 17%. This hypothesis appeared to be wrong, because we overestimated the initial rate and decrease of major complications, as explained before.

3.7. Conclusions and implications

Using a computerized DSS and audit & feedback for implementation of the clinical guidelines for the management of hypertension in pregnancy did not result in statistically significant less major maternal complications when compared to a minimal implementation strategy of audit & feedback only. Process evaluation showed that users of the computerized decision support system were positive about the system, but the use of the system could be improved.

4. Ethics approval and consent to participate

Ethical approval was granted June 12th 2008, VUmc. Reference number 2008/138.

5. Consent for publication

Not applicable.

6. Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

7. Competing interests

Not applicable.

8. Funding

The Netherlands Organization for Health Research and Development (ZonMw) funded this project (project no. 170883003).

9. Authors' contributions.

SL collected the data and drafted the manuscript. RH conceived of the study, participated in its design and coordination, and helped to draft the manuscript. LW collected the data. MH analyzed the data. MT conceived of the study, and participated in its design and coordination and helped to draft the manuscript. MW conceived of the study, and participated in its design and coordination, and helped to draft the manuscript. All authors read and approved the final manuscript.

Acknowledgements

We would like to acknowledge the 16 hospitals and the coordinating gynecologists for their cooperation in data sampling: E.A.M. van den Akker (Onze Lieve Vrouwe Ziekenhuis, Amsterdam), H.P. Oosterbaan (Jeroen Bosch Ziekenhuis, Den Bosch), K.M. Paarlberg (Gelre Ziekenhuis, Apeldoorn), C. Renes-Zeyl (Amstelland Ziekenhuis, Amstelveen), H.G.I. van Weering (Rode Kruis Ziekenhuis, Beverwijk), J.P. Lips (Kennemer Gasthuis, Haarlem), N.W. Schuitemaker and T.E. Vogelvang (Diakonessenhuis, Utrecht), P. Hummel (Medisch Centrum Alkmaar), K. de Boer (Rijnstate Ziekenhuis, Arnhem), R. Kok (Bernhove Ziekenhuis, Oss), I. de Graaf (Spaarne Ziekenhuis, Hoofddorp), J. Persoons (Beatrix Ziekenhuis, Gorinchem), A. Franx and C. van Oirschot (Elisabeth Ziekenhuis, Tilburg), A. Kwee and M. Ouddijk (Univerisitair Medisch Centrum Utrecht, Utrecht), F. Lotgering (Radboud University Medical Centre Nijmegen, Nijmegen) and T. Medema (Bovenij Ziekenhuis, Amsterdam). Furthermore, special thanks to research midwives from the University Medical Centre Utrecht for collecting data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.preghy.2018.08.451.

References

[1] B.M. Sibai, S.N. Caritis, E. Thom, M. Klebanoff, D. McNellis, L. Rocco, R.H. Paul, R. Romero, F. Witter, M. Rosen, R. Depp, Prevention of preeclampsia with low-dose aspirin in healthy, nulliparous pregnant women. The National Institute of Child Health and Human Development Network of Maternal-Fetal Medicine Units, N. Engl. J. Med. 329 (1993) 1213–1218.

[2] I.J. Perry, D.G. Bevers, The definition of pre-eclampsia, Br. J. Obstet. Gynaecol. 101 (1994) 587–591.

[3] R.J. Levine, J.C. Hauth, L.B. Curet, B.M. Sibai, P.M. Catalano, C.D. Morris, R. DerSimonian, J.R. Esterlitz, E.G. Raymond, D.E. Bild, J.D. Clemens, J.A. Cutler, Trail of calcium to prevent preeclampsia, N. Engl. J. Med. 337 (1997) 69–76.

[4] J. Golding, The jamaica low dose aspirin study group: a randomised trial of low dose aspirin for primiparae in pregnancy, Br. J. Obstet. Gynaecol. 105 (1998) 293–299.

[5] R.A. Odegard, L.J. Vatten, S.T. Nilsen, K.A. Salvesen, R. Austgulen, Risk factors and clinical manifestations of pre-eclampsia, Br. J. Obstet. Gynaecol. 107 (2000) 1410–1416.

[6] D. Subtil, P. Goeusse, F. Puech, P. Lequin, S. Blausque, G. Breart, S. Uzan, P. Marquis, D. Parmentier, A. Churlet, Aspirin (100 mg) used for prevention of pre-eclampsia in nulliparous women: the Essai Regional Aspirine Mere-Enfant study (Part one), Br. J. Obstet. Gynaecol. 110 (2003) 475–484.

[7] S.H. Luitjes, M.G. Wouters, T. König, K.W. Hollander, M.E. van Os, M.W. van Tulder, R.P. Hermens, Hypertensive disorders in pregnancy: a review of international guidelines, Hypertens Pregnancy 32 (4) (2013) 367–377, https://doi.org/10.3109/10641955.2013.808663.

[8] J.M. Schutte, N.E.W. Schuitemaker, J. van Roosmalen, E.A. Steegers, Dutch maternal mortality committee: Substandard care in maternal mortality due to hypertensive disease in pregnancy in The Netherlands, Br. J. Obstet. Gynaecol. 115 (6) (2008) 732–736.

[9] R. Grol, J. Grimshaw, From the best evidence to the best practice: effective implementation of change in patients' care, Lancet 362 (2003) 1225–1230.

[10] J. Grimshaw, M. Eccles, J. Tetroe, Implementing clinical guidelines: current evidence and future implications, J. Contin. Educ. Health Prof. 24 (Suppl I) (2004) S3–S37.

[11] J. Grimshaw, M. Eccles, TetroeJ. Toward evidence-based quality improvement. Evidence (and its limitations) of the effectiveness of guideline dissemination and implementation strategies 1966–1998, J. Gen. Intern. Med. 21 (Suppl 2) (2006) S14–S20.

[12] A.D. Oxman, M.A. Thomson, D.A. Davis, R.B. Haynes, No magic bullets: a systematic review of 102 trials of interventions to improve professional practice. CMAJ153, 1995, pp. 1423–1431.

[13] G. Jamtvedt, J.M. Young, D.T. Kristoffersen, M.A. O'Brien, A.D. Oxman, Audit and feedback: effects on professional practice and health care outcomes, Cochrane Database Syst. Rev. (2006) CD000259.

[14] M.A. O'Brien, S. Rogers, G. Jamtvedt, A.D. Oxman, J. Odgaard-Jensen, D.T. Kristoffersen, L. Forsetlund, D. Bainbridge, N. Freemantle, D.A. Davis, et al., Educational outreach visits: effects on professional practice and health care outcomes, Cochrane Database Syst. Rev. 17 (2007) CD000409.

[15] A.P. Farmer, F. Legare, L. Turcot, J. Grimshaw, E. Harvey, J.L. McGowan, F. Wolf, Printed educational materials: effects on professional practice and health care outcomes, Cochrane Database Syst. Rev. (2008) CD004398.

[16] B. Chaudhry, J. Wang, S. Wu, M. Maglione, W. Mojica, E. Roth, S.C. Morton, P.G. Shelleke, Systematic review: impact of health information technology on quality, efficiency and costs of medical care, Ann. Int. Med. 144 (2006) 742–752.

[17] R. Grol, M. Wensing, Implementatie: effectieve verbetering van de patiëntenzorg, Elsevier Gezondheidszorg, Maarssen, 2006.

[18] M.P. Heringa, M.G. Wouters, H.J. Vreeling, G. Schürer, Rapport pilotstudie BOS-GBS, Utrecht, 2006.

[19] M.D. Wüst, M.G. Wouters, G. Schürer, H.J. Vreeling, M.P. Heringa, Het BOS-GBS project: een nieuwe vorm van gebruik en evaluatie van een NVOG-richtlijn, Posterpresentatie Gynaecongres, Nijmegen, 2006.

[20] Guideline Hypertensive Disorders in Pregnancy, Utrecht: The Dutch Society of Obstetrics and Gynaecology, 2005.

[21] Guideline Chronic Hypertension in Pregnancy, Utrecht: The Dutch Society of Obstetrics and Gynaecology, 2005.

[22] S.H. Luitjes, M.G. Wouters, A. Franx, H.C. Scheepers, V.M. Coupé, H. Wollersheim, et al., Study protocol: cost effectiveness of two strategies to implement the NVOG guidelines on hypertension in pregnancy: an innovative strategy including a computerised decision support system compared to a common strategy of professional audit and feedback, a randomized controlled trial, Implement Sci. 5 (2010) 68.

[23] S.H. Luitjes, M.G. Wouters, A. Franx, A.C. Bolte, C.J. de Groot, M.W. van Tulder, R.P. Hermens, Guideline-based development of quality indicators for hypertensive disorders in pregnancy, Hypertens. Pregnancy. 32 (1) (2013) 20–31.

[24] W. Ganzevoort, A. Rep, G.J. Bonsel, W.P.F. Fetter, L. van Sonderen, J.I.P. de Vries, H. Wolf, A randomised controlled trial comparing two temporising management strategies, one with and one without plasma volume expansion, for severe and early-onset pre-eclampsia, BJOG 112 (2005) 1358–1368.

[25] W. Ganzevoort, A. Rep, J.I.P. de Vries, G.J. Bonsel, H. Wolf, Prediction of maternal complications and adverse infant outcome at admission for temporizing management of early-onset severe hypertensive disorders of pregnancy, Am. J. Obstet. Gynecol. 195 (2006) 495–503.

[26] N. Schuitemaker, J.W. Briet, J. van Roosmalen, et al., Substandard care BIJ moedersterfte, Ned Tijdschr Obstet Gynaecol 114 (2001) 77–78.

[27] C.M. Koopmans, D. Bijlenga, H. Groen, S.M. Vijgen, J.G. Aarnoudse, D.J. Bekedam, et al., HYPITAT study group. Induction of labour versus expectant monitoring for gestational hypertension or mild pre-eclampsia after 36 weeks' gestation (HYPITAT): a multicentre, open-label randomised controlled trial, Lancet 374 (9694) (2009) 979–988.

[28] K. van der Tuuk, C.M. Koopmans, H. Groen, B.W. Mol, M.G. van Pampus, HYPITAT study group. Impact of the HYPITAT trial on doctors' behaviour and prevalence of eclampsia in the Netherlands, BJOG 118 (13) (2011 Dec) 1658–1660.

[29] J.J. Zwart, A. Richters, F. Ory, et al., Eclampsia in the Netherlands, Obstet. Gynecol. 112 (2008) 820–827.

[30] A. Heselmans, S. Van de Velde, D. Ramaekers, R. Vander Stichele, B. Aertgeerts, Feasibility and impact of an evidence-based electronic decision support system for diabetes care in family medicine: protocol for a cluster randomized controlled trial, Implement Sci. 5 (8) (2013 Aug) 83.

[31] S.M. Mourad, R.P. Hermens, J. Liefers, R.P. Akkermans, G.A. Zielhuis, E. Adang, R.P. Grol, W.L. Nelen, J.A. Kremer, A multi-faceted strategy to improve the use of national fertility guidelines; a cluster-randomized controlled trial, Hum. Reprod. 26 (4) (2011) 817–826.

[32] N. Chaillet, E. Dube, M. Dugas, F. Audibert, C. Tourigny, W.D. Fraser, A. Dumont, Evidence-based strategies for implementing guidelines in obstetrics: a systematic review, Obstet. Gynecol. 108 (2006) 1234–1245.

[33] J. Ovretveit, D. Gustafson, Evaluation of quality improvement programmes, Qual Saf Health Care 11 (2002) 270–275.